GEOCHEMISTRY AND MINERAL FORMATION IN THE EARTH SURFACE

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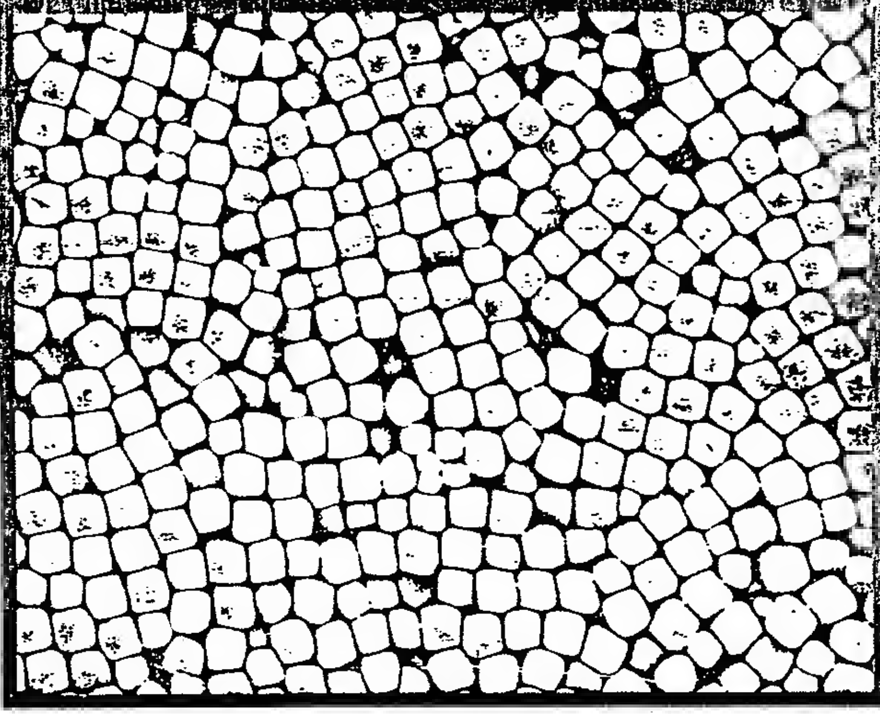

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DIAGENETIC CRYSTALLIZATION RHYTHMITES (DCRs) OF DOLOMITE - BARITE - CALCITE IN KARST ENVIRONMENT, GEBEL ABU GHORBAN, RED SEA COASTAL ZONE, EGYPT

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ABSTRACT

A small atrata-bound barite occurrence located in the Middle Miocene evaporites of tha Red Sea waa ayetematically investigated. The barite ia mostly confined with karatic features within an intercalated dolostone layer. It occurs together with dolomite, calcite and anhydrite mainly in a cement-filled cavity. The geometric diatributions proved that these minerals were developed during syndiagenetic crystallization generationa corresponding to the diagenetic crystallization rhythmites (DCRs). The genetic argument of this barite type may axplain the mechanism of the rhythmic formation in Karst.

INTRODUCTION

The present work is an attempt to undarstand one type of rhythmic barite taxture developing in karst. Small barite occurrencs, located in the weatern aide of Gebel Abu Ghorban, Red Sea, hae bean assigned for investigation, Gebel Abu Ghorban occurs in the coastal zona of the Red Sea, 55 Km S. of Quseir and 3 Km S. of Um Gheig leed-zinc mine (Fig. 1a).

The data are based mainly on the fiald observations supported by detailed investigations of oriented polished slabs and patrographic atudies. Beeides, geometric relationshipa, aa recorded in the fisld and under the microacope are répresented and classified. The preaant observations revealed the congruent relation between the barite and karst faatures and auggest the space and time of the cryetallization of the barite during the diagenetic differentiation of the karat cementing materiala.

Noteworthy, the main barite deposit of the Red Sea coast occurs in Wadi El Gerera (Elba region), 500 Km S. of Quseir. Thia depoait ia of vein type and it waa aesumed previously to be of hydrothermal origin.

GENERAL GEOLOGY AND LITHOSTRATIGRAPHY

The area of Gebel Abu Ghorban occupies about 6 aquare Km. It is covered mainly by sedimentary rocks of Middle Miocene age and Recent terraces. These sediments overlay unconformably the Pre-Cambrian basement rocks which repreeent the western high ridges of the Red Sea coast. The sedimentary outcrops are of relatively moderate to low relief. Their elevation decreases generally towards the present shore line to the eaat. The most conspicuous hill in Gebel Abu Ghorban rises up to 207 m above aea level.

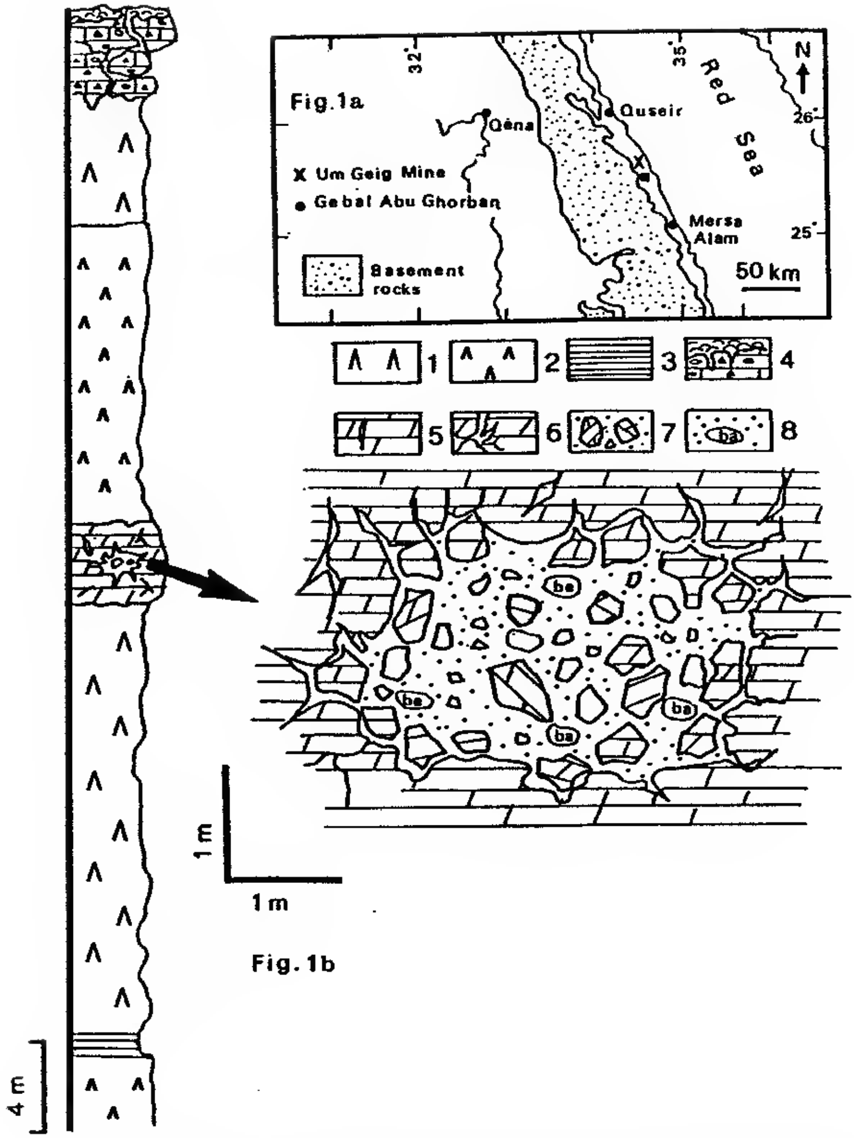


Fig. 1 ; a) Location map; b) Generalized lithostratigraphic section of the Abu Dabbab Formation in the western side of Gebel Abu Ghorban and schematic drawing of the karst filling cavity. 1 = gypsum ; 2 = anhydrite ; 3 = shale; 4 = karstified & silicified limestone encrusted by surficial calcareous crusts ; 5 = karstified dolostone ; 6 = crackle breccia ; 7 = collapsed breccia fragments, 8 = tufaceous materials with barite nodules (ba).

The Middle Miocene sediments in the study area are differentiated into the following two formations considering the nomenclature of the National Stratigraphic Subcommittee classification of the Miocene rocks of Egypt (El Gezeery and Marzouk, 1974). They are arranged from the oldest to the youngest:

- Gebel El Rusas Formation
- Abu Dabbab Formation

Gebel El Rusas Formation consists mainly of bedded marly limestone at the top, and a thin succession of sandstones and conglomerates at the base. The rocks of this formation exhibit different erosional and Karst features. Their present topographic surface is highly brecciated and silicified and characterized by the deposition of surficial calcareous crusts of "caliche" type (El Aref, 1981 ; El Aref and Amstutz, 1983 and El Aref et al, 1985). Abu Dabbab Formation makes up the main sedimentary outcrops in the area of Gebel Abou Ghorban. This Formation, in the western side of Gebel Abu Ghorban, attains a thickness of about 50 m (Fig. 1b). It consists mainly of alternated gypsum and anhydrite with shale intercalation and caped by fractured and brecciated limestone. A layer of dolostone, up to 3 m thick occurs intraformationally within the middle part of these evaporitic rocks. The uppermost exposed surfaces of this formation are also characterized by the development of surficial calcareous crusts. These crusts show features suggesting a downwards deposition by water percolation to karstified substrata.

KARST FEATURES

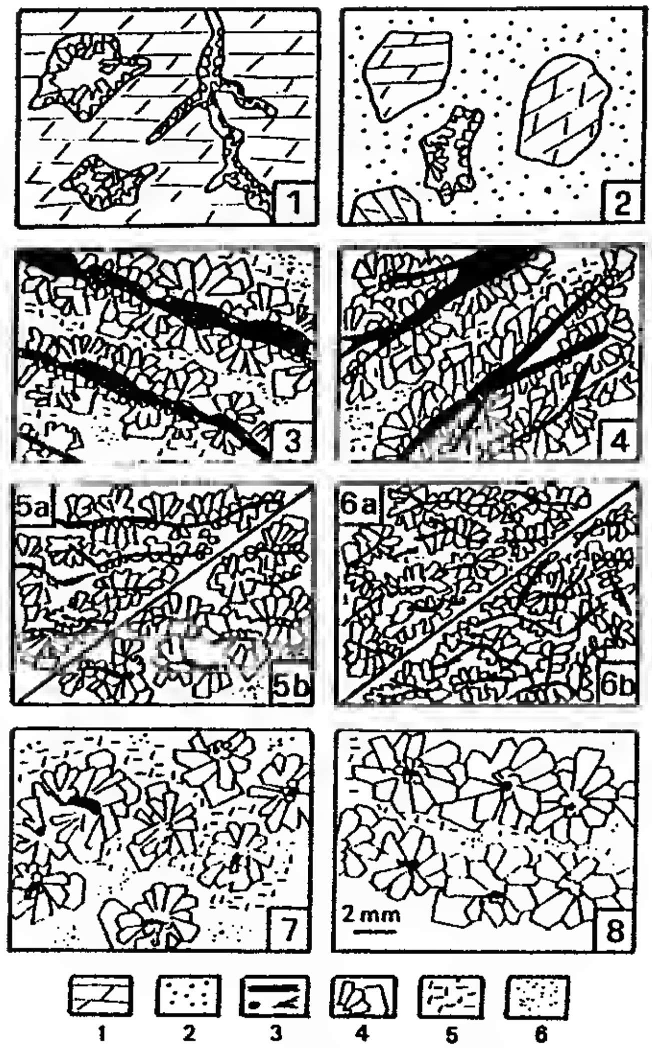
The Middle Miocene rocks in the area of Gebel Abu Ghorban represent a distinctive karst landform. It is dominated by cone hills and cockpits forms and characterized by the development of solutional features forming cavities and erosional surfaces. The cavities are commonly recognized at the contacts between the sediments and the underlying basement rocks, as well as between the two Middle Miocene formations and/or within the carbonate layers. The upper exposed surface of both formations are dissected by vertical and horizontal solutional channels, cracks and veinlets which grew usually in all directions giving rise to brecciation. These surfaces are caped by silicified surficial calcareous crusts of "caliche type".

The dolostone layer, interbedded in the evaporitic succession of the Abu Dabbab Formation contains a semirounded solutional cavity, up to 2x3 m in diameter (Fig. 1b and Fig. 3a). The cavity is completely filled with variable proportions of fragments embedded in very fine and partially consolidated calcareous material. These fragments are of subangular to subrounded shape ranging in diameter from cobbles to fine pebbles and sand sizes. They are mostly of dolostone composition and derived mainly from the roofs and walls of the cavity (Fig. 3b). The proper dolostone is commonly fractured. Some of these fractures are concentrated around the filling cavity forming crackle breccia.

The matrix of the cavity consists mainly of spongy porous calcareous material resembling the calcareous tufa of Irion and Müller (1968). Microscopically, these materials are made up of irregular clot-like masses or network streaks of brownish micrite connected and encrusted by clearer and coarser grained calcite, up to 50 μ in diameter. They may be remains of algal filaments or laminae and moss debris (Fig. 3c). These materials include geodes and nodular forms of barite together with dolomite, zoned calcite and anhydrite.

GEOMETRIC CONSIDERATION

The barite crystals are found mainly within the dolostone layer of the Abu Dabbab Formation. In particular, they are confined within the solutional



ɟ. 2 : Geometric diatribution patterns of the barita with
ɪematic simplification of the subsequent rhythmic crystallization
ɪerations (description in the text). Scala in square No. 1 1 =
.ostone ; 2 = tufaceous materials of the filling cavity ; 3 =
ɪe grained dolomite with algal laminae and micro-organic struc-
·es (generation I) ; 4 = barite of different morphologic forms
ɜneration II) ; 5 = calcite ; 6 = anhydrite (5 & 6 = generation
).

karst features displaying the following geometric forms and types (types 1-8 in Fig. 2):

e) eymmetrical filling of solutionsl fractures, cracks and grooves within the proper dolostone (type 1 in Fig. 2).

b) drusy filling of geodes, vugs and grooves within the tufacsous matrix of the solutional filling cavity (type 2 in Fig. 2).

c) bsrite nodules within the tufsceoue matrix of tha filling cavity (Fig. 3d). Theee barite nodulee rsngs between 5-15 cm in dismeter snd display the main barite forms in the studied occurrence.

The megascopic and microscopic observstions on the oriented croes-cut slabe snd thin eections of the barite noduies disciosed that they are formed by rhythmic alternations of derk and light bands and streaks (Fig. 3e). The derk sress are of brown colour and consist of fine grsined doiomite together with elgal lsminae (Fig. 3f), whereae the light bands consist of harite with or without calcite and enhydrite. The diffsrent geometric types of the bsrite rhythmites, considering the shaps of the dark sreas, are drawn and ciassified in Fig. 2 (typee 3-8). Typs 3 repreeents slternating parallel to subparallel bands, up to 5 mm thick. Their upper surfaces exhibit U-shaped grooves or groove-cast like texture (Fig. 3e). In type 4 of Fig.2, the dark bands sre usually branched into thinner connected or disconnected fine etresks, but still showing a isyering appearance. Typa 5a represents psrallel undulated thin atreaks or laminae. They range between 0.5-2 mm in thickness and may branch in some inetances. Type 5b is s thin interrupted streaks of wavy sppearance forming flaser liks structura. Howevar, type 5s could be considered as a trensitional psttern between types 4 and 5b. In type 6a, the wavy interrupted streaks are branched forming transitionsl pattern between types 5a, 5b and type 6b (Fig. 4a). Type 6b displsys an interconnected network pattern consisting of brsnched and connected streaks (Figs. 4a and b). Types 7 and 8 represent a epherulitic or "orbiculsr"-iike (Fontboté, 1981) pattarn of barite cryetsls with or without s center of dark spots. The barite spherulites are either irregulsrly distributed (type 7) er connected with each other having e layering appearance (type 8).

SEQUENCE OF CRYSTALLIZATION

The microscopic observations do indicats thst the rhythmic characters of the barite nodules are due to the repetition of three subsequent generations of crystallization. These observations are based on the study of the morphology of the minersl constituents within the barite nodules and their internal geometric relstionships. The subsequent rhythmic crystallization generstions are achematically eimplified in Fig. 2. Generation I (calied starting sheet by Fontboté, 1981) ie represented by the dark bands, stresks or spots. It coneists of cloudy aggregatss of fine grained dolomite together with fiisments of algsl laminae and cellulsr organic structuras. Generation I is usually steined with reddieh brown colours probably dua to the existence of srganic metter. Generstion II forms the major part of the light rhythmic bsnds (Figs. 4a and b). It consists mainly of barite crystsls of different sizes and shepes. They are symmetrically arranged in bipolsr patterns growing in both sidee of the sterting sheet (gensrstion 1). Generation II exhibits commonly geopetal growth snd contains no soiid inclusions. According to the differences of the morphology and aize of tha barite crystals, generstion II is dietinctly divided into threa subgenerstion : s,b and c. Subgeneration IIs is displsyed by very fine to fine barite crystals, rsnging between 0.05 to 0.3 mm in diameter. They are of subhedral forms and directly depeaited on the outer surfsces of generstion 1. The contact between generetion 1 and subgenerstion IIs is sbrupt indicsting tha change in phssea during the crystallization. The crystals of subgeneration IIs are xenomorphic towsrds generation 1 and show subhedrsi termination into subgeneration IIb. Subgenerstion IIb is dieplayed by siightiy to notsbiy eiongate and bladded shaped barite crystsis, ranging between 0.5 to 2.5 mm in dismeter. Theee crystale sre ususily arranged in epherulitic pattarn or flower like sggregates or they are of radiai orientetion (Figs. 4c and d). Subgeners-

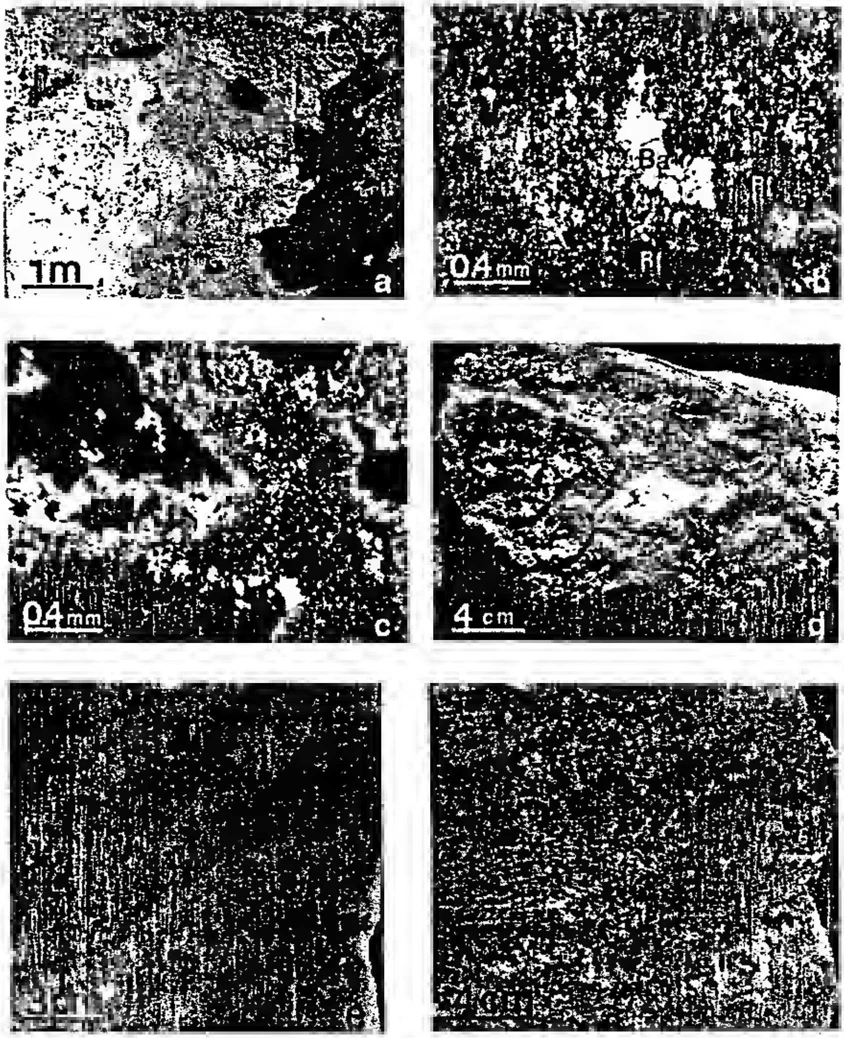


Fig. 3: a) Field photograph of the karst filling cavity (arrow). b) Photomicrograph (//N) of the cavity filling material consisting of rock fragments (Rf) embedded in calcareous tufaceous matrix. The matrix includes drusy filled geodes of barite (Ba). c) Photomicropgraph (+N) of the "tufaceous" matrix of the cavity consisting of spongy porous calcareous material. d) Barite nodule (Ba) embedded in the calcareous matrix of the filling cavity. e) Polished slab of barite "DCR". The dark bands consist of fine grained dolomite (generation I) and the light bands consist of barite (generation II). Generation III is not visible. f) Polished slab showing filaments of algal laminae (arrow) in generation I.

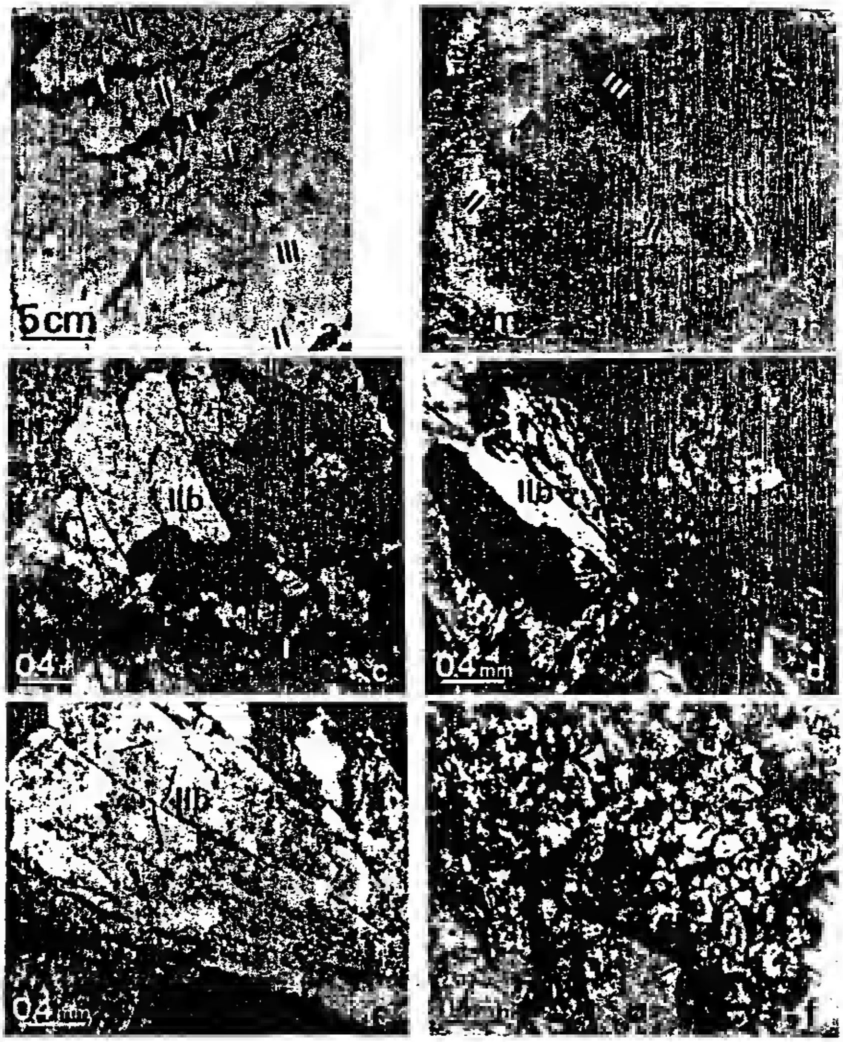


Fig. 4 : a) Thin section (//N) of rhythmic dolomite (generation I) and barite (generation II).GenerationIII is represented by empty voids (white). Generation I forms interrupted, wavy, parallel and branched streaks gradually changed to network pattern (Left corner of the photo). Notice, the geopetal growing of generation II into generation III. b) Polished slab of network rhythmic type corresponding to type 6b of Fig. 2. c) Photomicrograph (+N) showing the development of the differenct generations I, II and III and subgeneration IIa, IIb and IIc. Generation III is displayed by felty anhydrite. d) Spherulitic growth of barite crystals showing the encrustation of subgeneration IIb by subgeneration IIc (photomicrograph, +N). e) Barite crystals of subgeneration IIb followed by the crystallization of subgeneration IIc (photomicrograph, +N). f) Euhedral barite crystal of subgeneration IIc (Left corner of the photo) encrusted by basic hexagonal shaped and zoned calcite (photomicrograph, +N).

tion IIa shows graditional development into subgeneration IIb. The subgeneration IIb has idiomorphic ends towards subgeneration IIc and generation III (Figs. 4d and e). Subgeneration IIb is caped in some instances by almost euhedral and relatively large barite crystals which form the subsequent subgeneration IIc in the crystallization sequence (Fig. 2 and Figs 4d and e) and which ranges in diameter between 1-3 mm. From the geometric point of view , it could be concluded that the morphologic subdivisions of generation II represent different growth atagea produced aubaequantly during the crystallization of this monomineralic barite phase. Ganeration III ia mainly displayed by the development of the reaidual empty apaces left by generation II. In aome inatancas, these spaces are partially lined or completely filled by calcite and/or felty anhydrite. The calcite occura aa aggregatea of equidimensional basic hexagonal, granular or wedge shaped and zoned crystals usually stained by a reddish colouration (Fig. 4f). Theae charactaristic morphologic forms of calcite auggest a fresh water origin according to the description of Krumbein, 1968 and Folk, 1974. The calcite of generation III filla the apaces between generation II and ia usually followed by the deposition of the falty anhydrita.

GENETIC IMPLICATION

The barite occurrence of Gebal Abu Ghorban ia typically atrata-bound. It ia moatly confined within tha karst filled cavity included in the doloatone layer of the Abu Dabbab Formation.

The megaacopic and microscopic observations ravealed that the barite crystala ara closely associated with cryptalgal laminae, fine grained dolomite, calcite and anhydrite. These minarala and the associated organic remains are aymmetrically arranged in rhythmic texturea of different geometric patterns. The observed characteriatic rhythmitea are due to repetition of three subaequent cryatallization generations, i.e. fine grained dolomite with cryptalgal laminae, barita cryatala with different morphologic forms and primary empty spaces (vuga) filled with calcita and/or anhydrita. The type of the rhythm could be expreaaed ae CBABC. The evidences for the paragenetic positions of the above mentioned minerala are datermined from the follwoing recognizable faaturea ; a) the bipolarity, spherulitic growth, subhedral termination, idiomorphism and the change of aize of the barite crystala of generation II, and b) the infilling of the remaining spaces and the development of the primary empty voids of generation III. The morphologic charactera of the barite cryatala reflect the primary ralative rate of growth of the cryatal facsa according to the equilibrium condition of the medium (Rodriguez - Clementa, 1982).

The geometric distribution pattarns of these rhythmites may ba interpreted as primary sedimentary fabrics including layering laminaa, streaks, wavy or flaser bedding, geopetal growth and groove-cast. The cross cutting or network fabrics seem to be formed aa a result of the deformational processes caused during the cryatal enlargement. These geometric patterns correspond to typea D, F, H and S of the claaaification of the ore rhythmites of Levin and Amatutz (1976) and are comparabla with typea 3, 4a, 4b and 9 of the classification of Fontobtá (1981) for the basic gaometric patterns of diagenetic crystallization texturas.

Moreover, the lack of any evidenca of raplacement, corrosion or pseudomorphism in generation II, lead to the concluaion that the present rhythmites were developed during processes of fractionation cryatallization and differentiation thet took placa befora the consolidation of the rocks, e.g., during the diagenesia, in a closed karst environment, (called diagenetic crystallization rhythmites "DCRs" by Fontboté and Amstutz, 1980). The main featurea of the different crystallization genarationa of the observed rhythmites are closely similar to those of the diagenetic rhythmites of Fontboté and Amstutz, 1982. The diagramatic representation of the barite DCRs of

Gebel Abu Ghorban is illustrated in Fig. 5. The formation of barite in karst

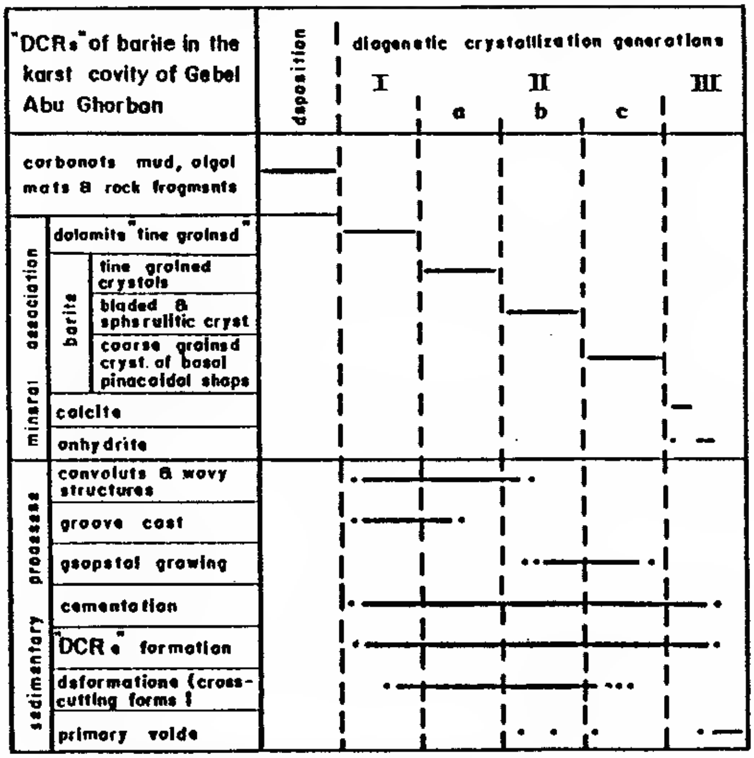


Fig. 5 : Schematic paragenetic sequence of the barite "DCRs" of Gebel Abu Ghorban.

characterisee the percolation zone of the karat model by Bernard (1976) and Zuffardi (1976).

The rhythmic diagenetic crystallization was proposed previously by Amstutz and Park (1967) and Amstutz and Bubenicek (1967). Reviews and description of different occurrences of ore rhythmites in marine facies, have been presented in Levin and Amstutz, 1976 ; Fontboté and Amstutz, 1980 ; Fontboté, 1981 ; Fontboté and Amstutz, 1982 and Sameniego, 1982. Synsedimentary rhythmicity of barite in Arkansas, Nevada and Meggen (Germany) were described by Zimmermann (1967, 1969, 1970 and 1976) and Zimmermann and Amstutz (1961 and 1964 "a,b,c"). DCRs in Egypt is recently described by El Aref (1984) for the iron sulphide and sulphur occurrences of the Ranga mine and by El Aref et al (1985) for the crystallization of surficial calcareous crusts of caliche type.

Megascopic rhythmic textures of ores were observed in Karst by Bernard, 1976 ; Padelino et al, 1976 ; Zuffardi, 1976 ; Schulz, 1976 and 1982. These authors support the syndiagenetic origin of the ore rhythmites. While, Bogacz et al. (1973) still proposed metasomatic replacement origin for the ore rhythmites in open cavities.

The development of the karst features and the associated barite DCRs of Gebel Abu Ghorban appear to be genetically related to the formation of the karst filling mass of Um Gheig mine (El Aref and Amstutz, 1983) and the deposition of the surficial calcareous crusts of the "caliche" type (El Aref, 1981 and El Aref et al, 1985). Regarding the age of the karstification and barite formation, it seems to be younger then the Middle Miocene sediments,

most probably Pliocene or Pleistocene.

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